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REMOTE SENSING APPLICATIONS IN THE FRAME OF "URBAN GEOLOGY" PROJECT

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Abstract

In the frame of the "Urban Geology" project of IGME a lot of remote sensing applications were carried out: DSMs creation and accuracy verification, orthorectification of very high resolution satellite data, data fusion, multitemporal and multisensor image analysis, land cover and land use change detection e.t.c. The applications that took place in the pilot case of Nafplio are presented in this study.

Key words: *DSM, orthorectification, fusion, multitemporal data, Corine Land Cover.*

1. Introduction

One of the major projects of the Institute of Geology & Mineral Exploration (IGME) regard a modern issue of geology called "Urban Geology". In the frame of that project there was a need for a high accuracy Digital Surface Model "DSM" covering the whole country and update high resolution satellite data for the prefectures capital cities. Thus, many remote sensing applications were carried out: DSMs were created from different satellite data and accuracy control was done. The DSMs and the derived products were compared with respective data from topographic maps and airphoto stereopairs. The DSMs were used for the orthorectification of high resolution images and other applications such as slope and aspect map creation, environmental planning et.c. High resolution (Ikonos and Quickbird) data was also orthorectified. Those data is used for the land use classification, land cover change detection and the urban area mapping. Land cover change detection was done using multitemporal and multisensor satellite data covering the last thirty years. For the broader area of Nafplio all the changes that occurred in the urban and suburban area were detected and mapped. The urban expansion rate was estimated and the human interferences in the natural landscape were recorded. Land use classification and change detection was also done. The scope of this study was to briefly describe all the remote sensing applications carried out in the frame of "Urban Geology" project.

2. DSM creation from satellite data and accuracy control

For the purposes of "Urban Geology" project there is need for a high accuracy DSM. The DSM should be used for the orthorectification of high resolution images and other applications such as slope map creation, environmental planning et.c. Thus, there is a huge pressure for very accurate elevation data covering the entire country surface.

The official sources of elevation data with a Pan-Hellenic coverage are only two: the topographic maps of the Greek Military Service and DSMs created from airphoto steropairs provided by the Ministry of Agriculture in ASCII format.

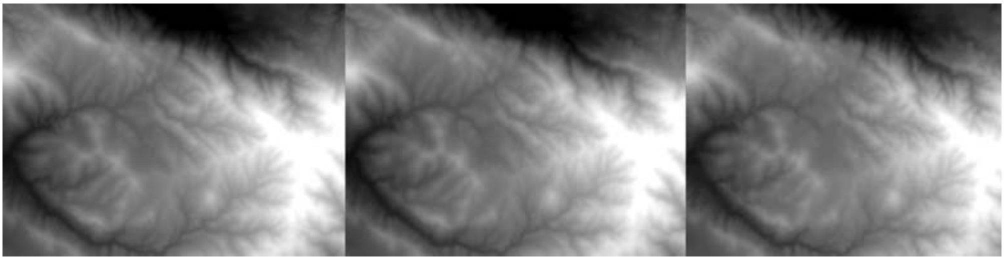

Fig.1: (left): Part of Cartosat DSM with a pixel size of 20m; (middle): Part of Airphoto DSM with a pixel size of 20m; (right): Part of DEM created from the 1/5000 topographic maps with the same pixel size.

The most popular data sources for the creation of DTM are the digitized contours of the toporaphic maps. The 1:50.000 topographic maps, with a contour interval of twenty meters, present a nominal horizontal accuracy of 20 meters and a nominal vertical accuracy of 10 meters with 90% confidence. The data were in most cases extracted with photogrammetric techniques from aerial stereo-photographs during the 80's. The usual update rate for these maps ranges from ten to twenty years. As a result in many cases a lot of changes have been done during this period and there is a need for updating. The 1:5.000 topographic maps present better nominal horizontal and vertical accuracy as the contour interval is 4m but in many areas there are also intermediate contours of 2 or 1m but the update rate is even worst and most of the maps have been created during the seventies.

The Ministry of Agriculture provide DSMs in ASCII format created from airphoto stereopairs. The pixel size of that DSM is twenty meters and the nominal vertical accuracy ranges between 2 and 3 meters. The data is distributed in tiles of 12 km^2.

Image stereopairs form satellite sensors seem to provide a quite accurate and cost affordable source of elevation data. Thus we had to assess the accuracy of DSMs created from different satellite stereopairs. DSMs from ASTER, Cartosat and ALOS data were created and compared with the DEM from the 1/5000 topographic maps and the DSMs of the Ministry of Agriculture. Different accuracy controls pointed out that the DSMs created from the Cartosat (Fig. 1) and the ALOS stereopair are suitable for the needs of the Urban Geology project (Tsombos et al. 2008; Tsombos and Nikolakopoulos 2008; Nikolakopoulos et al. 2009). In general, it was proved that the accuracy of the DSMs from ALOS and Cartosat data ranges between 2.5 and 5m and it comparable with the nominal vertical accuracy of the DSMs of the Ministry of Agriculture.

3. Data fusion

In the frame of "Urban Geology" project of IGME there is need for very accurate remote sensing multispectral data with the maximum spatial resolution context. This data is used for the updating of the existing topographic maps, for land use classification, land cover change detection and the urban area mapping.

Six different fusion algorithms Modified HIS (Siddiqui Y., 2003), Local Mean Method (LMM) (De Béthune et al. 1998), Local Mean and Variance Method (LMVM) presented by (De Béthune et al. 1998), Wavelet (King et al. 2001; Lemeshewsky G., 1999; Lemeshewsky G., 2002)., Ehlers (Ehlers M., 2004; Ling et al. 2007; Ehlers et al. 2008) and Pansharp (Zhang Y.,1999) were applied to Quickbird data set in order to assess the quality of the fused products.

The data set covering Nafplio area corresponds to a Quickbird panchromatic image (0.6 m) and its

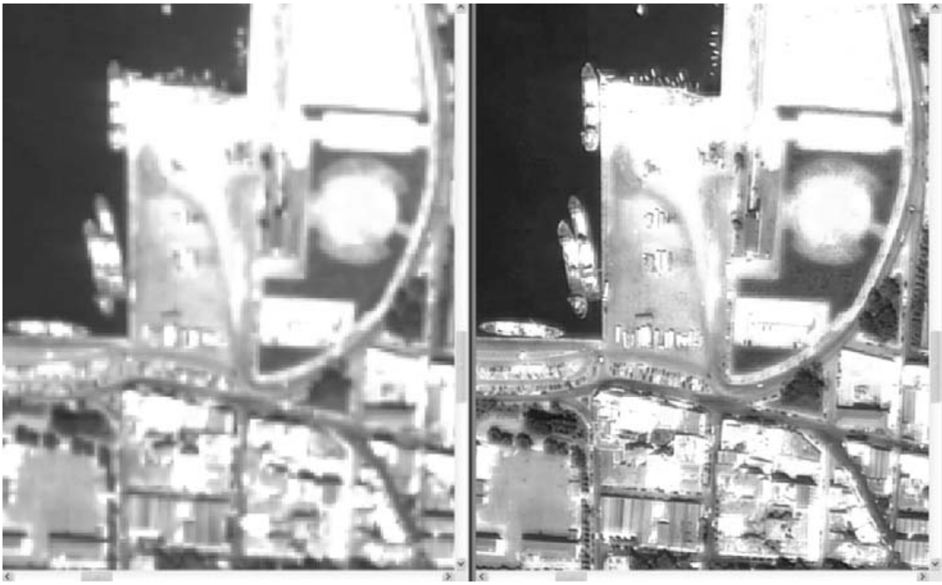

Fig. 2: (left): Part of the original Quickbird image of Nafplio with 0,6m pixel resolution; (right): the fused image with the Ehlers algorithm with the same resolution.

synchronous acquired multispectral channels (2.4 m). The panchromatic band and the multispectral bands have been fused in images that combine the spectral characteristics of the multispectral data with the relatively high spatial resolution of the panchromatic band. In all cases, the nearest neighborhood resampling method was applied. For each fused image the following issues have been examined: a) the visual qualitative result (Fig. 2), b) the statistical parameters of the histograms of the various frequency bands and c) the correlation coefficient. Those criteria are in accordance with the general quality assessment criteria that were described in previous studies (Wald et al. 1997, Chavez et al. 1991). It was proved (Nikolakopoulos and Tsombos, 2009) that all the above mentioned algorithms are suitable for the fusion of Quickbird data.

4. Multitemporal and multisensor image processing

In this contribution, the potential and the restrictions of combined optical air and spaceborne imagery for digitally measuring the urban expansion of Nafplio city in the last thirty years was assessed. For this work, the spatial resolution of the available images is, besides the time period between the acquisitions, the most crucial parameter. Minor or major changes have to be identified from the available images with predefined resolution. So there was a necessity to use images that cover the broader area with a similar spatial resolution.

4.1 Data sets used

In order to locate and map the urban expansion we have used satellite data and topographic maps of the Hellenic Army Geographical Service (1/5:000 scale). The remote sensing data used are the following:

- A quickbird multispectral image with a spatial resolution of 0.6m acquired on 3/9/2003.

Fig. 3: Airphoto mosaic from the Ministry of Agriculture.

Fig. 4: The declassified aerial image.

- An airphoto mosaic from the Ministry of Agriculture (Fig. 3). The data is distributed in tiles of 12 km^2 with a spatial resolution of 1m. The mosaic was created from airphotos acquired on 2000.
- An orthorectified Landsat 2 MSS image acquired on 21 /8 /1977 with a spatial resolution of sixty meters.
- A declassified aerial image acquired at 12/7/1975. Declassified Satellite Imagery consists of approximately 50,000 images that were taken from 1963 to 1980. These photographic images were collected by the KH-7 Surveillance System and the KH-9 Mapping System. The images have variable scales and the image quality can be variable. Cloud cover is common. The film and print products are produced from a duplicate negative source. The specific image was acquired from the KH-9 Mapping System and it has a nominal resolution that ranges between 20 and 30 feet (6-9 meters). The film was scanned at 7 microns and its final size overpassed 1.3GB (Fig. 4).

Fig. 5: The orthorectified aerial image of Nafplio at 1/25.000 scale.

4.2 Digital image processing

The Quickbird have been orthorectified using ground control points (gcp's) collected with a DGPS. A DEM from the digitized contours from the 1/5000 topographic maps was used for the orthorectification.

The declassified aerial photo was orthorectified taking into account more than 200 gcp's distributed in whole image. The gcp's were collected from an orthorectified Landsat 7 panchromatic image with 15m pixel size. A SRTM DEM has been used for the orthorectification of the image. The resampling method for warping the data was nearest neighborhood interpolation and the new pixel size of 4 meters.

Then the pansharp fusion algorithm was used in order to merge the declassified aerial photo (Fig. 5) with the Landsat 2 MSS image (Fig. 6). The result images (Fig. 7) have an improved spatial resolution of 4m and the spectral characteristics of the original landsat 2 MSS image.

4.3 Urban expansion

In order to map and estimate the intensity and the spatial pattern of urban expansion in Nafplio we digitized the urban boundaries based on two period satellite data obtained in 1977 and 2003 respectively. The urban area was divided into two major categories:

- The urban zone characterized as a dense build – up area.
- The suburban area, surrounding the urban zone and directly connected with it, characterized as a less dense build – up area, compared to urban area.

For the better understanding of the urban expansion spatial pattern, we considered necessary to digitize additionally the transportation network of the covering study area. Digitized roads were grouped into two categories:

- Main roads including primary roads such as national roads, national rural roads, urban streets, etc.
- Local roads including secondary roads such as not connected streets, unpaved roads, tracks, etc.

The following maps represent, in different colors, the urban - suburban zones and the main - local roads located in the broader study area at 1977 (Fig. 8) and at 2003 (Fig..9). Finally, the new constructions during the period 2000 - 2003 were digitized from the Quickbird image (Fig. 10).

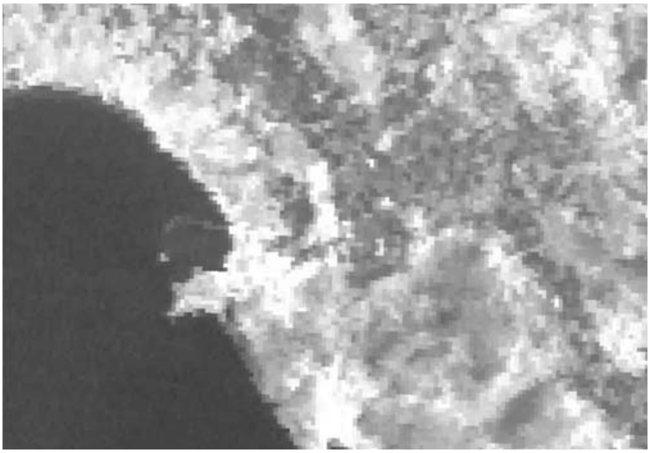

Fig. 6: The Landsat2 MSS image of Nafplio at 1/25.000 scale.

Fig. 7: The fused image of Nafplio at 1/25.000 scale.

5. Results

From the GIS analysis of the remote sensing data, the following results were carried out:

The total surface growth of the city is approximately 77% (Zervakou et al. 2008). The urban area growth is almost double (98%, mainly observed north of the city of 1977), while suburban area increased at 61% (mainly observed east of the city of 1977). The results are presented in Table 1.

From 1977 up to 2003, according to satellite data and derived maps, we observe that the clear urban area expanded covering the preexisting suburban area, while the suburban area expanded covering the rural area. The urban area extended to north in parallel with coastal zone which is characterized by beautiful landscapes. This means that urban growth is clearly connected with local morphology and other economic – tourist factors. The suburban area expanded easterly, following the preexisting main road network and becoming at the same time better connected with the vital economic – tourist area of Nafplio city. Since 1977, the road network within the urban and suburban area has become denser and better connected (Zervakou et al. 2008).

During the same period the population of Nafplio city was continuously increasing (30% more residents in 20 years) according to the official inventories (Table 2). The annual rate of the population

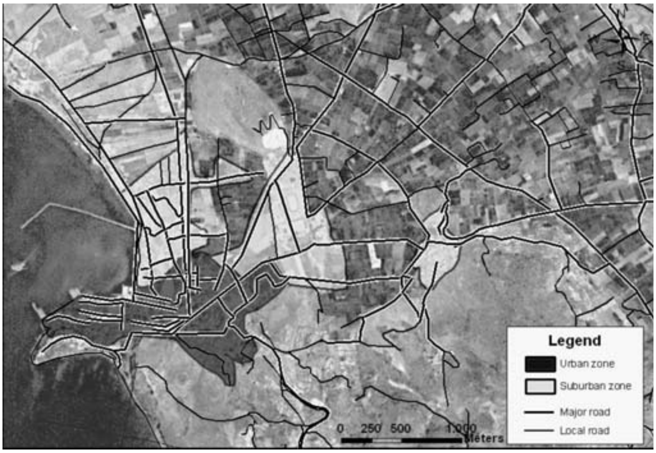

Fig. 8: The road network in Nafplio city in 1977. With red colour the Urban zone and with yellow the Suburban zone.

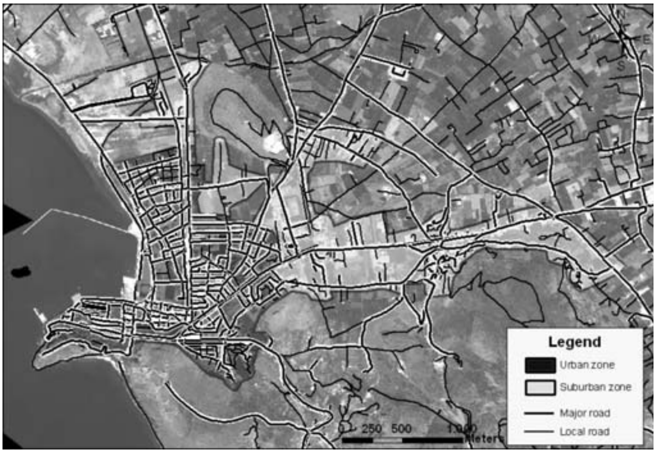

Fig. 9: The road network in Nafplio city in 2003. With red colour the Urban zone and with yellow the Suburban zone.

Table 1. Urban and Suburban area in Nafplio and total difference during the period 1977 -2003.

1977		***2003***	
Type	Area (km2)	Type	Area (km2)
Urban area	1,031	Urban area	2,038
Suburban area	1,391	Suburban area	2,247
Total area	2,422	Total area	4,285
Total Difference 1977- 2003			1,863 Km2

increase is 1.6%. The rate of new buildings construction during the period 2000 - 2003 was only 0.05%. The total number of the new constructions was 202 (Table 3). From the new buildings 124 were classified as new houses, 5 as pools and 72 as other constructions (Table 4).

The road network for the 1977 was digitized from the 1/5.000 topographic maps. The major road network was increased by 30Km during the period 1977-2003. The local area network was increased by 77km. The total increase of 107 km (Table 5) gives an annual rate of 1.21%.

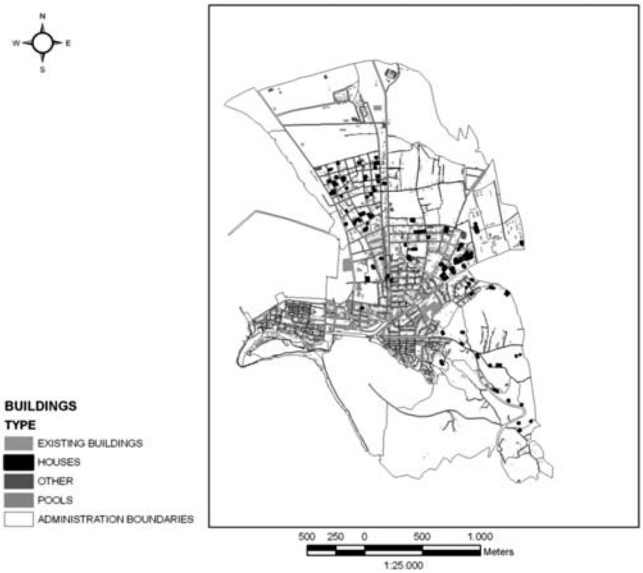

Fig. 10: New buildings in the city of Nafplio from 2000 to 2003.

Table 2. Population of Nafplio city in 1981, 1991, 2001.(source: National Statistical Service).

Year	Population	Différence
1981	10.611	-
1991	11.897	1.286
2001	13.822	1.925

Table 3. Number of constructions in the city of Nafplio.

Year	**2000**	**2003**
No of Constructions	3574	3776
Difference		202

Table 4. Type of the new constructions in the city of Nafplio.

Houses	124
Pools	5
Other constructions	72
Total	202

Table 5. Road network in the broader area of Nafplio (length in km).

	1977 (from the topographic maps)	2003
Major road network	215,889	245,720
Local road network	124,456	201,764
Total	340,344	447,484

6. References

Chavez, P.S. Jr., Sides, S.C., Anderson, J.A., 1991. Comparison of three different methods to merge multiresolution and multispectral data : Landsat TM and SPOT Panchromatic, *Photogrammetric Engineering and Remote Sensing*, Vol. 57, N° 3, pp. 295-303.

De Béthune Stanislas, Fabrice Muller, Jean-Paul Donnay, 1998. Fusion Of Multispectral And Panchromatic Images By Local Mean And Variance Matching Filtering Techniques, *Fusion of Earth Data*, Sophia Antipolis, France, 28-30 January 1998.

Ehlers Manfred, 2004. Spectral characteristics preserving image fusion based on Fourier domain filtering, *Proc. of SPIE* Vol. 5574 p. 1-13.

Ehlers M., Klonus S., and Astrand P.J., 2008. Quality assessment for multi-sensor multi-date image fusion, *Proc. XXIth Int. Congr. ISPRS*, Beijing, China p. 499-506.

King, Roger and Wang, Jianwen, 2001. A Wavelet Based Algorithm for Pan Sharpening Landsat 7 Imagery, 2001. *Erdas Field Guide* 2008. Vol. II pp. 358.

Lemeshewsky, George P, 1999. Multispectral multisensor image fusion using wavelet transforms, *Proc of SPIE* Vol. 3716, p. 214-222.

Lemeshewsky, George P, 2002b. Multispectral Image sharpening Using a Shift-Invariant Wavelet Transform and Adaptive Processing of Multiresolution Edges, *Proc of SPIE*, vol. 4736, p. 189-200.

Ling Y., Ehlers M., Usery L., and Madden M., 2007. FFT-enhanced IHS transform method for fusing high resolution satellite images, *ISPRS Journal of Photogrammetry & Remote Sensing* 61, 381-392.

Nikolakopoulos Konstantinos G. & Panagiotis I. Tsombos, 2009. "Ameliorating the spatial resolution of high resolution satellite data for use in urban areas". *Urban and Regional Data Management*, CRC Press, Editors A. Krek, M. Rumor, S. Zlatanova & E.M. Fendel, 2009, p.399-408.

Nikolakopoulos Konstantinos G., Panagiotis I. Tsombos & Lathourakis George, 2009. "Comparison of different along the track satellite stereo-pair for DEM Extraction", *29th EARSeL Symposium*, 14 έως 21 Ιουνίου 2009, Μεσογειακό Αγρονομικό Ινστιτούτο Χανίων. ΠΡΚ υπό Δημοσίευση.

Siddiqui Yusuf, 2003. The Modified Ihs Method For Fusing Satellite Imagery, *ASPRS 2003 Annual Conference Proceedings*, May 2003 Anchorage, Alaska, In Press.

Tsombos Panagiotis I., Konstantinos G. Nikolakopoulos & Lathourakis George, 2008. "DEM creation from Cartosat data and comparison to DEM from other sources". 15th International Symposium on Remote Sensing of the International Society for Optical Engineering, 15-19 September 2008 Cardiff, Wales, UK. *Proc. of SPIE*, Vol. 7106 p. 71061C1-12.

Tsombos Panagiotis I. & Konstantinos G. Nikolakopoulos, 2008. "DEM creation from ALOS data and comparison to DEM from other sources. A case study from Greece". *Proceedings of ALOS 2008 Primary Investigators Symposium*. Unpaginated CDROM

Wald, L., Ranchin, Th., Mangolini, M., 1997. Fusion of satellite images of different spatial resolutions: Assessing the quality of resulting images, *Photogrammetric Engineering and Remote Sensing*, Vol. 63,N° 6, pp. 691-699.

Zervakou D Alexandra, Konstantinos G. Nikolakopoulos, Panagiotis I. Tsombos & George P. Papanikolaou, 2008. Monitoring the urban expansion of Sparta and Nafplio cities using remote sensing and GIS techniques, *Proc. of SPIE*, Vol. 7104 p.7104071-12.

Zhang Y., A new merging method and its spectral and spatial effects, *International Journal of Remote Sensing*, vol. 20, 1999, pp. 2003-2014.